E_0 versus E_1 and $E_1 + \Delta_1$ optical transitions in the band structure of (Ga,Mn)As alloys

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The fundamental properties of the canonical dilute magnetic semiconductor (Ga,Mn)As: magnetic, optical, structural and electronic picture, are extremely sensitive to the growth temperature, post-growth annealing procedure, number of the adverse defects and the strain parameters.

Our resent efforts are aimed at the optimization of the low-temperature molecular-beam epitaxy (LT-MBE) growth conditions with the aim to fabrication epitaxial (Ga,Mn)As layers with the lowest level of undesirable defects, such as arsenic antisites, (As_{Ga}), and Mn interstitials, (Mn_I). The 100 nm thick (Ga,Mn)As layers for this study have been prepared at approximately 230°C on semi-insulating (001) GaAs substrates with the LT-MBE growth technique, with the Mn contents ranging from 0 to 1.6%. High-resolution X-ray diffraction measurements show that the investigated LT-GaAs and (Ga,Mn)As epitaxial layers have been pseudomorphically grown on GaAs substrate under compressive misfit strain with a rather low concentration of As_{Ga}, defects – in the range of 10^{19} cm^{-3}.

The low-temperature high-spectral-resolution optical studies of the energy gap (E_0) evolution of the (Ga,Mn)As epitaxial layers, obtained under the optimized conditions, have shown that the modification of the GaAs valence band caused by Mn incorporation occurs already for a very low Mn content, much lower than that required to support ferromagnetic spin–spin coupling in (Ga,Mn)As [1]. The combined low-temperature magnetic and photoreflectance studies have indicated that the paramagnetic–ferromagnetic phase transition in *p*-type (Ga,Mn)As takes place without imposing changes in the unitary character of the valence band with the Fermi level located therein.

The advanced optical investigations of the described above set of the GaAs/(Ga,Mn)As heterostructures with the combined photoreflectance and spectroscopic ellipsometry methods in a wide range of wavelengths (from 150 nm to 2000 nm) will be presented. Comparing the evolution of the optical transitions at E_0 with those at E_1 and $E_1+\Delta_1$ optical-transition spectral areas allows for better understanding the band structure modification in (Ga,Mn)As with increasing Mn concentration.

[1] L. Gluba, O. Yastrubchak, J. Z. Domagala, R. Jakiela, T. Andrearczyk, J. Żuk, T. Wosinski, J. Sadowski, and M. Sawicki, *Phys. Rev. B* (accepted 16 Feb. 2018).